# Space Weather Technical Forecast

Issued on Monday, 02 January 2023 at 00:57 Local

**This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales**

**Space Weather Forecast Headline: Chance of M-flares throughout. Increasing Chance of Electron flux and Active Fluence. Chance of G1/Minor Geomagnetic Storm intervals from late on day 2 (3rd).**

## Analysis of Space Weather Activity over past 24 hours

**Solar Activity:** Solar activity has been Low over the past 24 hours, with only a C3.8 flare at 01/0228 UTC from AR3176. There are currently six numbered active regions on the visible disc, with the newly numbered AR3181 (Hsx/Alpha) emerging round the southeast limb over the past 24 hours. AR3176 (Eao/Beta-Gamma) is the largest and most complex region on the disc, but showed some signs of decay, with reduction of penumbra and intermediary spots. The next complex region is AR3177 (Dsi/Beta), which is moderately large, with some close spots. There are two other moderately large regions on the disc; AR3179 (Dao/Beta) in the northwest and AR3180 (Dso/Beta) in the northeast, but both these groups are more open. The final region is AR3173 in the northwest, which has decayed through the period and is now classed as a Axx/Alpha. There were no obvious signs of Earth-Directed CMEs in the available imagery during the period.

**Solar Wind / Geomagnetic Activity:** Solar winds, as observed by DSCOVR and ACE were initially elevated to strong (550-620 km/s) but gradually declined to slightly elevated levels, near 460km/s. The density was generally below average (<5 nT). Total Interplanetary Magnetic Field (IMF), Bt, was Weak (~5nT) throughout, with only weak fluctuations in the north-south component, Bz, (+4/-5 nT). The Phi angle was predominantly positive (away from the Sun). These wind parameters are indicative of a positive coronal hole high speed stream connection and resulted in predominantly Quiet to Unsettled geomagnetic activity (Kp1-3), with an Active (Kp4) interval observed between 01/2100-2400 UTC).

**Energetic Particles / Solar Radiation:** The high energy proton flux (greater than 10MeV) as measured at GOES16 remained at background levels. High energy electron flux (greater than 2MeV) has been diurnally cycling between Moderate and High levels, with a peak of 2887 pfu at 01/1815 UTC. The 24-hour integrated electron fluence showed an increasing trend, rising above the active threshold. The observed fluence at 02/0000 UTC was 1.11e8 integrated pfu.

## Four-Day Space Weather Forecast Summary

**Solar Activity:** Low to Moderate activity is expected, with an ongoing daily chance of M-flares. There is a slight chance of X-class flares.

**Solar Wind / Geomagnetic Activity:** A CME which left the Sun on the 30th of December may cause a glancing impact at Earth either late on the 3rd Jan (Day 2) or early on the 4th Jan (Day 3). No other Earth directed CMEs are currently expected. The coronal hole influence is expected to gradually decline through days 1 and 2 (2nd and 3rd Jan). A further coronal hole enhancement is expected from day 3 (4th Jan) from either CH60/- or CH61/-. Quiet to Unsettled geomagnetic activity, with a chance of Active initially, is expected to become increasingly Quiet on day 1 (2nd). There is a chance of activity increasing to Unsettled to Active levels later on day

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2 (3rd) due to a glancing blow from the CME from the 30th December, but more likely from day 3 (4th) upon the arrival of a coronal hole CIR and high speed stream. There is a chance of G1/Minor geomagnetic storms from late on day 2 (3rd), but more likely from day 3 (4th) due to HSS/CH influences.

**Energetic Particles / Solar Radiation:** The high energy (greater than 10 MeV) proton flux observed by GOES-16 is expected to remain at Background levels throughout but with a chance of rising alongside any notable flares, giving a very slight chance of exceeding the S1/Minor Storm threshold. High energy electron flux (greater than 2MeV) observed by GOES-16 is likely to continue at Moderate to High levels, with a probable upward trend over the next couple of days. The associated 24 hour fluence is also expected to rise and is likely to exceed the Active (1e8 integrated pfu) threshold from day 1 (2nd).

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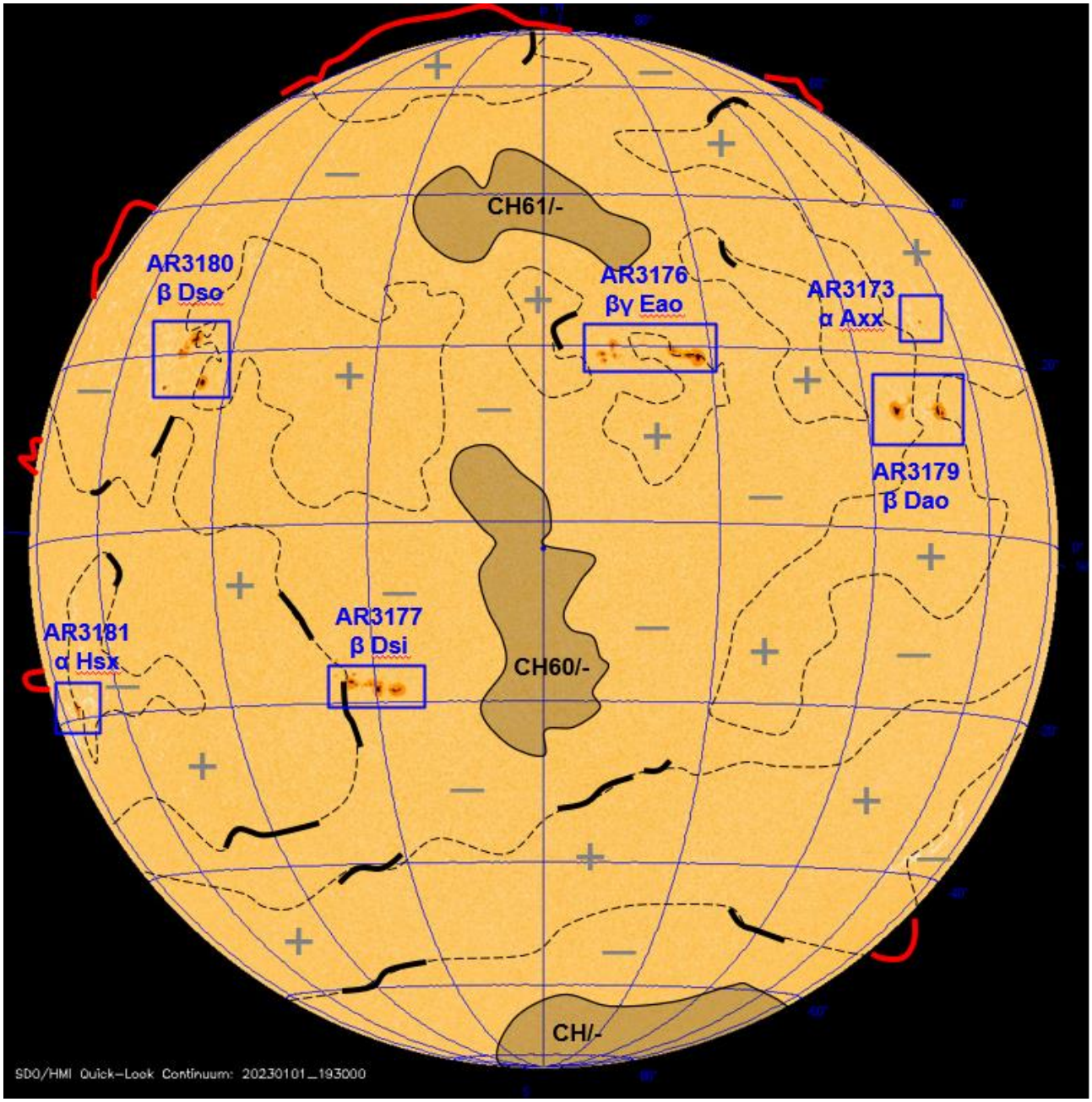
**Figure 1. Solar Analysis Valid 01/1930 UTC.**




**Key:** Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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## Geomagnetic Storms:

A coronal mass ejection (CME) observed in coronagraph imagery associated with the M1 flare at 30/1528 UTC from AR3176, has been analysed. The data suggests a possible glancing blow from the CME at Earth either late on the 3rd Jan (Day 2) or early on the 4th Jan (Day 3). However, this a low confidence forecast due to the limited (gaps) data available in the coronagraph imagery. Otherwise, no other Earth directed CMEs are currently expected.
Solar winds are currently elevated, around 500km/s, due to the ongoing connection with CH59/+. The effect of this is forecast to wane over the coming days, with winds gradually declining towards ambient levels. However, a further coronal hole enhancement is expected from day 3 (4th), from a connection with either CH60/- or CH61/-. Both these features are new or radically changed from previous rotation and thus persistence is offering poor guidance.

Quiet to Unsettled geomagnetic activity, with a chance of Active initially, is expected to become increasingly Quiet on day 1 (2nd). There is a chance of activity increasing to Unsettled to Active levels later on day 2 (3rd) due to a glancing blow from the CME from the 30th December, but more likely from day 3 (4th) upon the arrival of a coronal hole CIR and high speed stream. There is a chance of G1/Minor geomagnetic storms from late on day 2 (3rd), but more likely from day 3 (4th) due to HSS/CH influences.

| Geo-Magnetic Storm | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) | Day 2 (00-24 UTC) | Day 3 (00-24 UTC) | Day 4 (00-24 UTC) |
|---|---|---|---|---|---|---|
| Probability (Exceedance) | | | (%) | (%) | (%) | (%) |
| Minor or Moderate | G1 to G2 | No | 5 | 20 | 30 | 40 |
| Strong | G3 | No | 1 | 1 | 1 | 1 |
| Severe | G4 | No | 1 | 1 | 1 | 1 |
| Extreme | G5 | No | 1 | 1 | 1 | 1 |

## Geomagnetic Activity - Earthbound Coronal Mass Ejections

| Date/time 21.5R (UTC) | Halo: Full or Partial | Source | Source Location | Estimated Speed | Estimated Arrival Time | Comments |
|---|---|---|---|---|---|---|
| 31/0141 | Partial | M1 flare at 30/1528 UTC | AR3176 | 390 km/s | 03/1800 UTC | Low confidence. Limited shock expected. |

**Figure 2: ENLIL Ensemble showing potential CME arrival on 3rd January**

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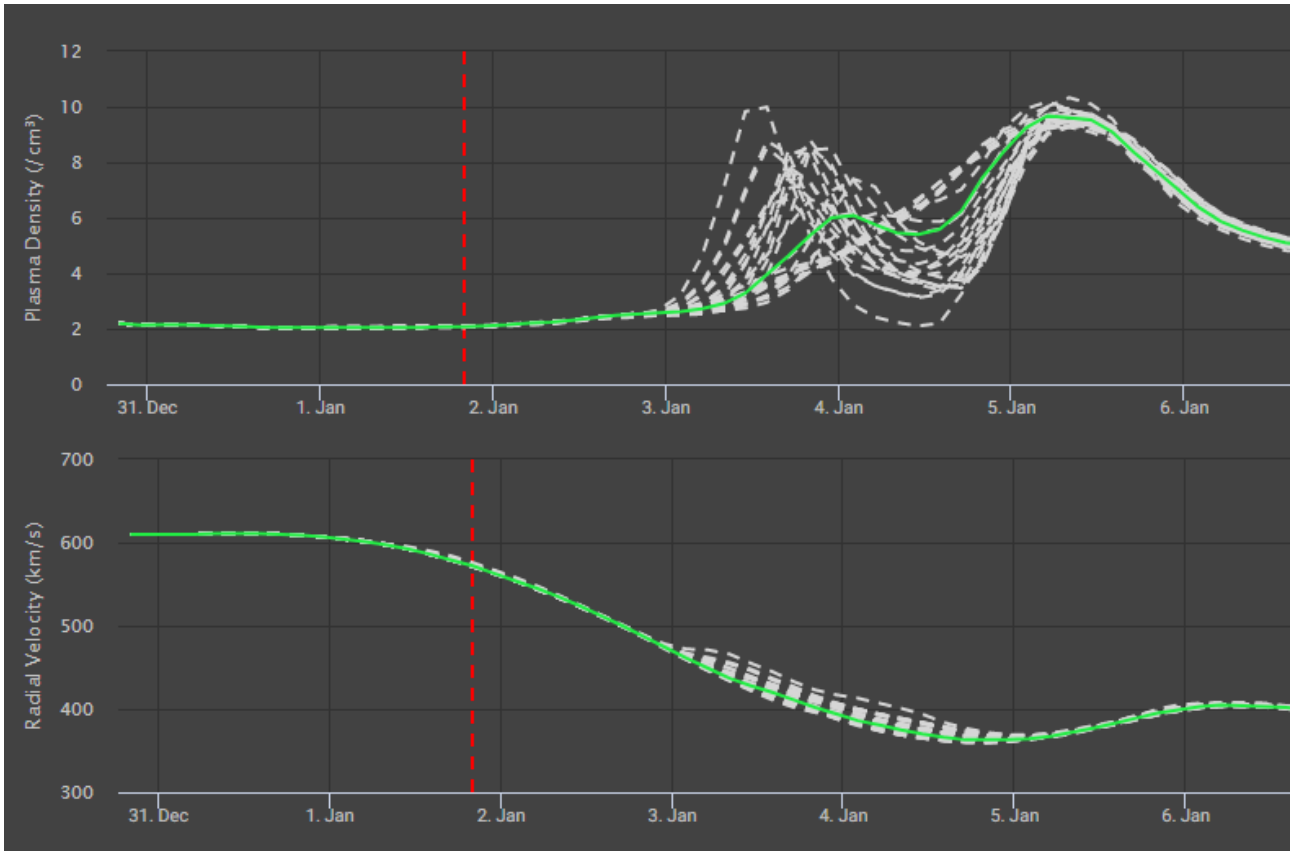


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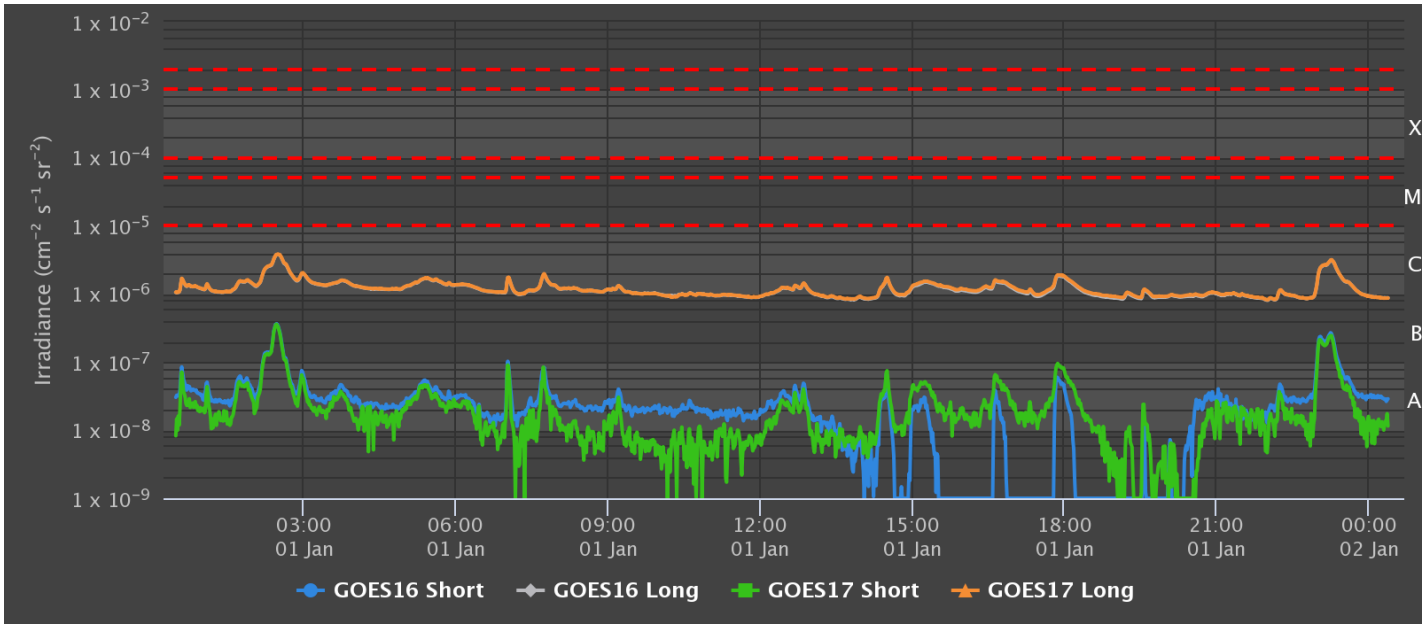
**Radio Blackouts - X-Ray Flares:**
Solar activity has been Low over the past 24 hours, with only a C3.8 flare at 01/0204 UTC from AR3176. There is a chance of activity increasing to moderate levels at times during the period, with isolated M-class flares, and there is a slight chance of an X-class flare.

There are currently 6 sunspot regions on the disc. The largest and most complex region is AR3176 (Eao/Beta-Gamma) which has just transferred across the meridian to the western hemisphere. There are also 3 other moderately large and mature beta regions, with penumbra on both sides (AR3177, AR3179 and AR3180). The two other regions on the disc are currently thought to be simple unipolars, but the newest region towards the southeast is still emerging from round the southeast limb, although appears to be a simple Hsx/Alpha configuration at time of writing.

Far sided products suggest there is potential for new regions to rotate onto the Earth facing disc later in the period, but these will need to be assessed if/when they do. Therefore, the flare risk remains consistent throughout, with no front sided regions forecast to depart during the period.

| X Ray Flares | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) | Day 2 (00-24 UTC) | Day 3 (00-24 UTC) | Day 4 (00-24 UTC) |
|---|---|---|---|---|---|---|
| Probability | | | (%) | (%) | (%) | (%) |
| Active | R1-R2 M Class | No | 30 | 30 | 30 | 30 |
| Very Active | R3 to R5 X Class | No | 5 | 5 | 5 | 5 |

**Figure 3: GOES X-Ray flares during the past 24 hours.**

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## Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) measured by GOES-16 is at Background levels. Any significant flares will bring a risk of proton flux rising at points during the period, with a slight chance of exceeding the S1/Minor Storm threshold. This risk increases slightly through the period, as AR3176 transits across the western hemisphere.

| Radiation Storms Probability (Exceedance) | Level ($cm^{-2}$ $sr^{-1}$ $s^{-1}$) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| **Active** | **≥ S1** | No | 5 | 10 | 10 | 10 |
| **Very Active** | **≥ S3 *** | No | 1 | 1 | 1 | 1 |

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

## High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed by GOES-16 is likely to be at Moderate to High levels, with an expected upward trend over the next couple of days due to the waning influence of CH59. Later in the period, if significant geomagnetic activity occurs due to a possible CME arrival and also the arrival of the next HSS, so the high energy electron flux may rapidly decrease to Background to Moderate levels.

The associated 24 hour fluence continues to show an upward trend, and it is likely that the Active threshold (1e8 integrated pfu) will be exceeded by day 1 (2nd). However, late in the period a decreasing trend may develop.

Electron fluence is currently above the Active threshold, which is in good agreement with the REFM guidance. Fluence is expected to remain above the threshold over the next few days, with REFM giving good guidance. Persistence is offering poor guidance with features on this rotation unlike the last.

| GEO Electron Environment Probability (Exceedance) | Level ($cm^{-2}$ $sr^{-1}$ $day^{-1}$) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| **Active** | **≥ 2 MeV ≥ $1x10^8$** | No | 90 | 70 | 60 | 30 |
| **Very Active** | **≥ 2 MeV ≥ $1x10^9$** | No | 1 | 1 | 1 | 1 |

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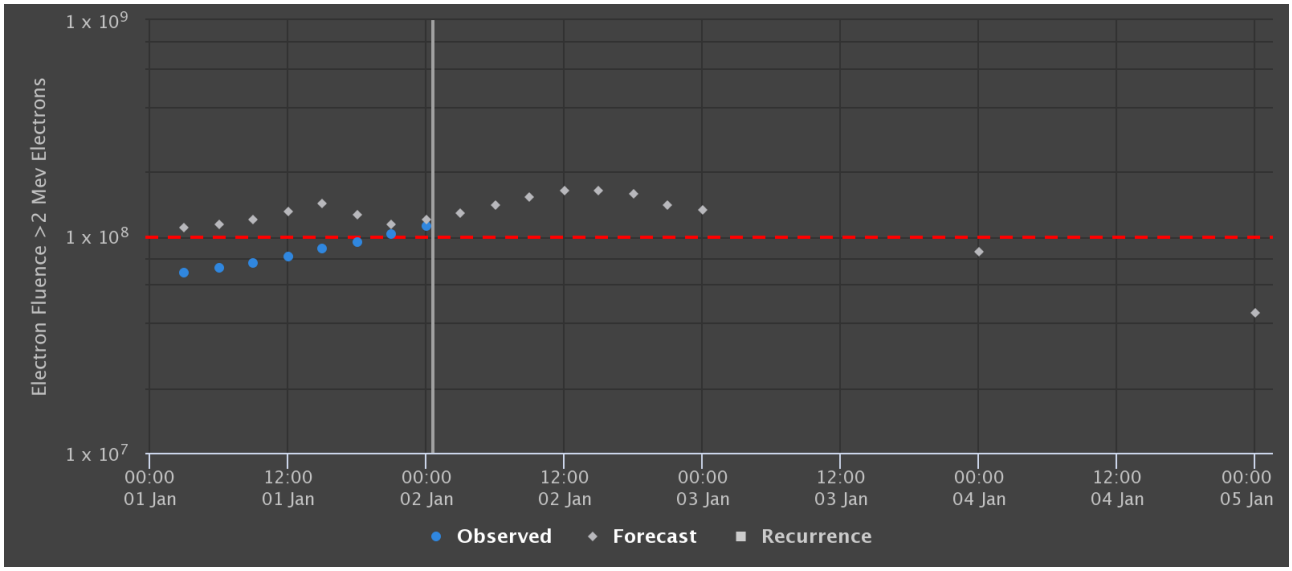
**Figure 4: Observed electron fluence from GOES-16 and REFM - fluence is currently above the Active threshold.**

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